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The Morphology Changes of Indentations in Press-in Tests of SS304 Under Tensile Stress

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In this paper, a stress maintaining jig was designed to introduce tensile stress to the specimen as simulated residual stress to facilitate press-in test on specimens loaded with tensile stress. The trend of the hardness value and differences in the diagonal lengths of the indentation of specimens with tensile stress were obtained. A finite element method numerical experiment was used to simulate the process of the press-in experiment. The results show that the hardness value and the diagonal lengths difference of indentations of SS304 are closely related, which can be considered as a foundation for residual stress measurement.

INTRODUCTION

Welded joints in pressure vessels and piping, as shown in Fig. 1, are found to be prone to suffering from stress corrosion cracks (SCCs); this is one of the crucial safety issues affecting the operation of pressure vessels. The crack formation is driven by three main factors: environment, material, and loading. Ren et al. (2017) found the residual stress introduced by welding processes can sometimes reach or even exceed the yield stress of the base material. Because the operational external loads on pressure vessels and piping are relatively small, the welding residual stress is regarded as the main driving force for the SCC crack growth. Therefore, methods to obtain the distribution of residual stresses in welded structures have become crucial in predicting the SCC crack growth rate.

Many studies have been carried out to test methods for measuring residual stress distributions. Mathar (1934) first proposed the hole-drilling method to measure the residual stress in metal materials. Soete and Vancrombrugge (1950) then added in the use of strain gauges to improve accuracy. Rendler and Vigness (1966) further improved the approach; details and instructions of this method were made available in the American Society for Testing and Materials' Standard ASTM 837 (ASTM International, 2008). Zhandano and Gonchar (1978) combined the hole-drilling method with the ring core method to create the deep-hole-drilling method for measuring through the thickness. Beaney and Procter (1974) and Smith et al. (1998), among others, applied this method to anisotropic materials. More recently, Prime et al. (2004) proposed the contour method, which has become a widely used method. If applied properly, these methods can give accurate measurements of the distribution of residual stresses in three dimensions. But all these are destructive tests, yielding irreversible damages to the specimen.

Nondestructive methods have also been proposed. Lester and Aborn (1925) introduced X-rays to measure residual stress in the 1920s. Macherauch (1966) improved upon this method further so that X-rays became a widely applicable approach for shallow surface residual stress measurement. In recent years, the neutron diffractometer was introduced to measure welding residual stress. Withers (2007) successfully mapped residual and internal stress using this method, but a zero-stress status of the material is a priori knowledge, which is not easy to obtain or ensure. Overall, nondestructive methods are usually quite costly and require special facility support, which makes them of limited availability.

Underwood (1973) introduced the press-in experiment to measure the surface residual stress, a method later known as the

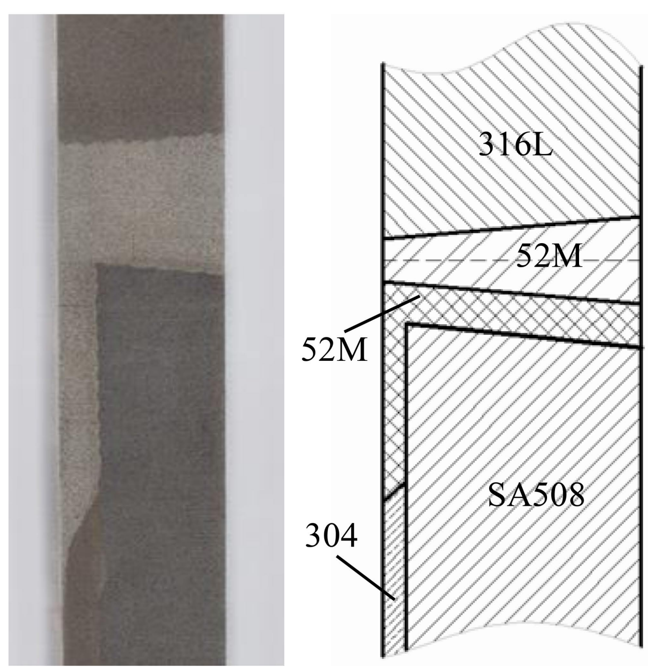

Fig. 1 Schematic diagram of the material component of a dissimilar welded joint in a pressure vessel

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